# REPORT DOCUMENTATION PAGE

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OMB No. 0704-0188



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| | 5c. PROGRAM ELEMENT NUMBER |
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| | 5e. TASK NUMBER |
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TP-1998-160

30

MEMORANDUM FOR IN-HOUSE PUBLICATIONS

FROM: PROI (TI) (STINFO)

10 Jul 98

SUBJECT: Authorization for Release of Technical Information, Control Number: AFRL-PR-ED-TP-1998-160
Dr. Quinn "AFRL Propulsion Directorate Briefing for Industry (Space Propulsion Thrust"
**NAECON Briefing** **(Statement A )**

20020823 043

**15. SUBJECT TERMS**

| 16. SECURITY CLASSIFICATION OF: | | | 17. LIMITATION OF ABSTRACT | 18. NUMBER OF PAGES | 19a. NAME OF RESPONSIBLE PERSON |
|---|---|---|---|---|---|
| | | | | | Leilani Richardson |
| a. REPORT | b. ABSTRACT | c. THIS PAGE | A | | 19b. TELEPHONE NUMBER *(include area code)* |
| Unclassified | Unclassified | Unclassified | | | (661) 275-5015 |

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std. 239.18

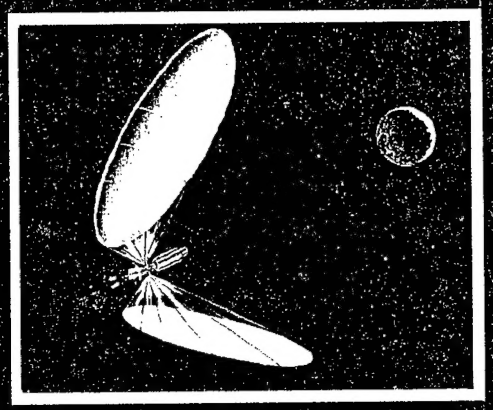
41 items enclosed

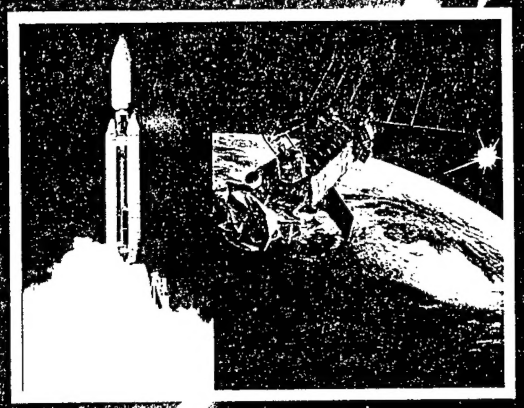
# Air Force Research Laboratory

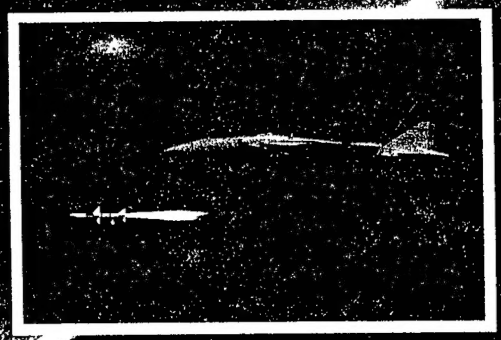
## Propulsion Directorate

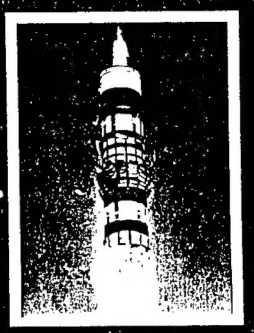
## Rocket Propulsion Division

Dr. Lawrence P. Quinn

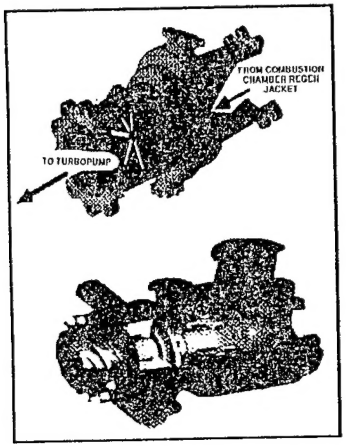








# Air Force Research Laboratory
# Rocket Propulsion Division

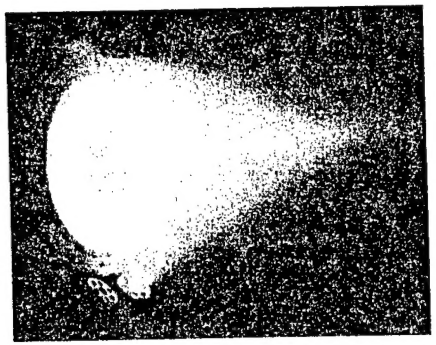



INTEGRATED POWERHEAD DEMONSTRATION

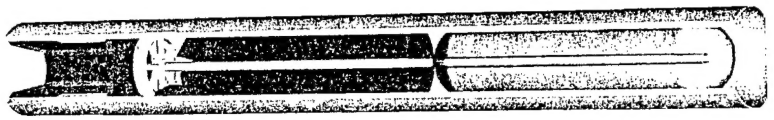
## Mission Statement

**Create Rocket Propulsion Technologies for the Warfighter to Control and Exploit Space & Air**

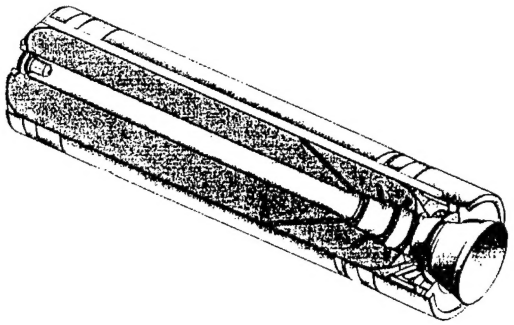
ADVANCED EXPANDER CYCLE ENGINE



HALL THRUSTER



HYBRID BOOST

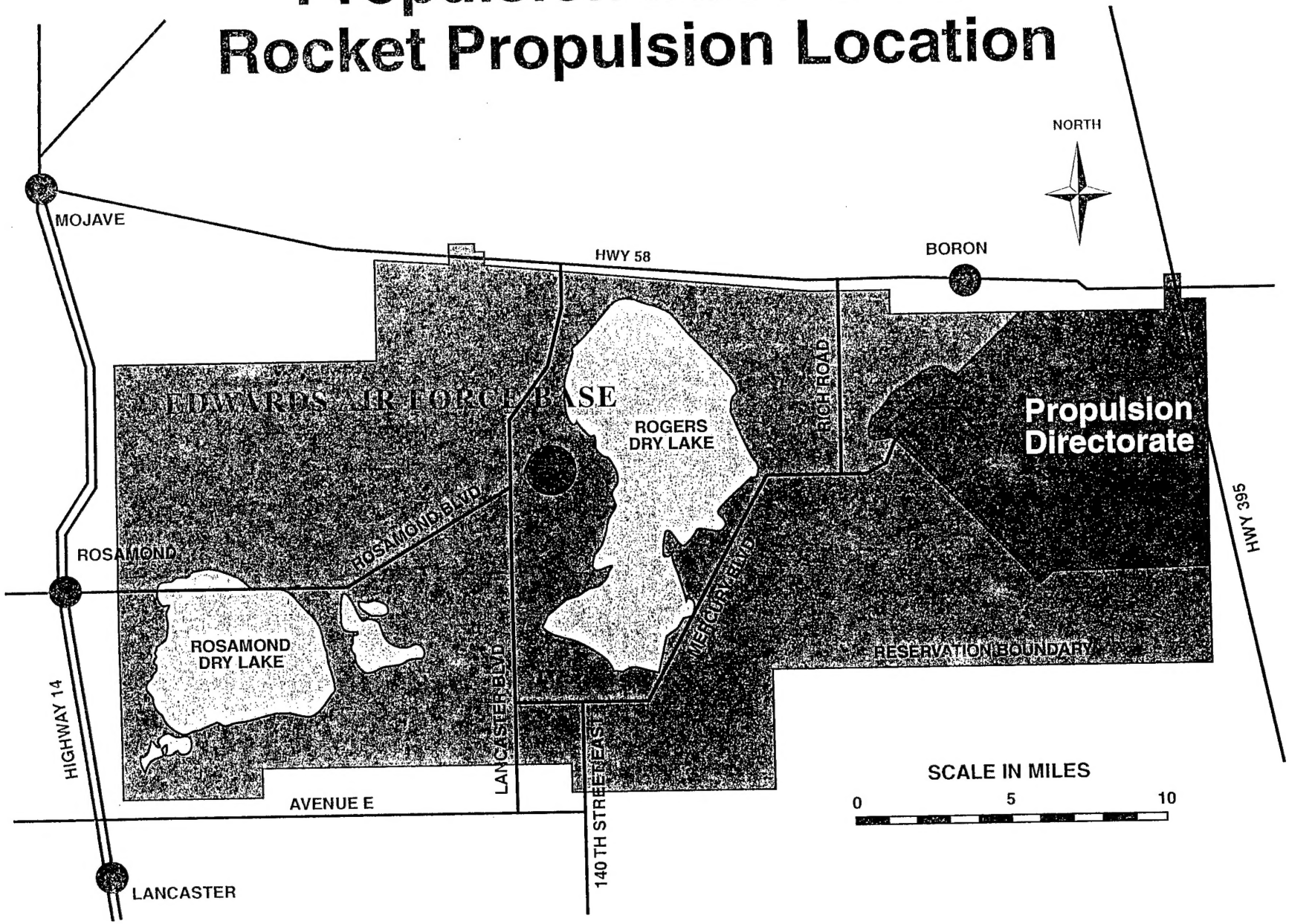


SUSTAINMENT MOTOR

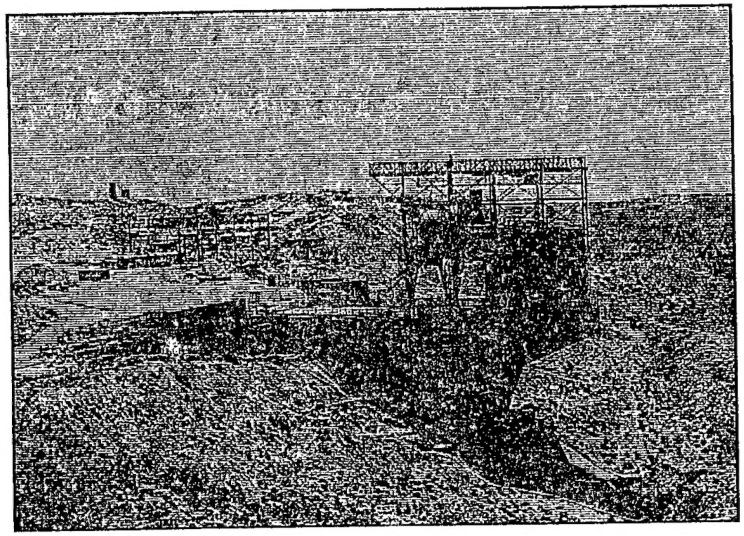
# Outline

- Who Are We?
- What Have We Done?
- Integrated High Payoff Rocket Propulsion Technology
- What Are We Doing?

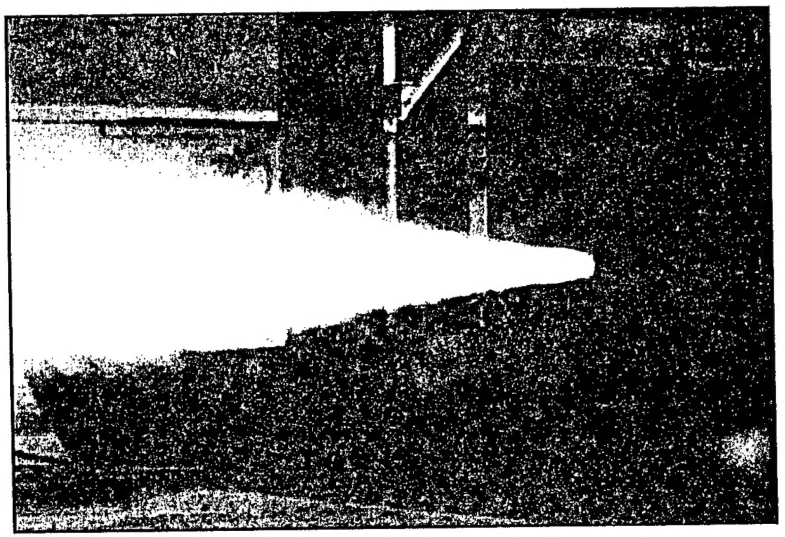
# Propulsion Directorate
# Rocket Propulsion Location

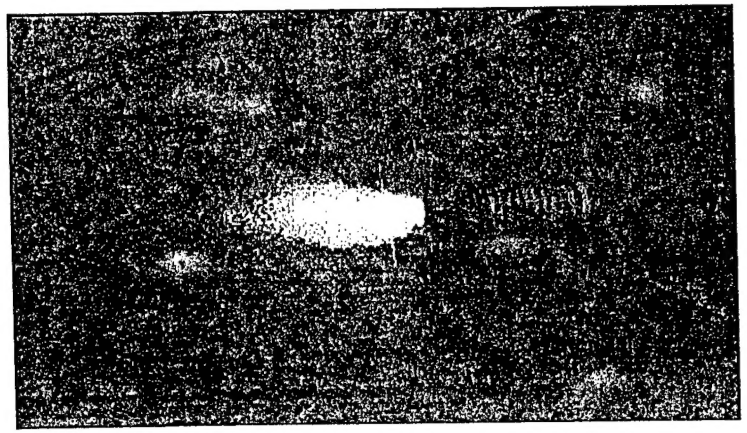


# Facilities



NINETEEN LIQUID ENGINE
STANDS TO 8,000,000 LBS THRUST

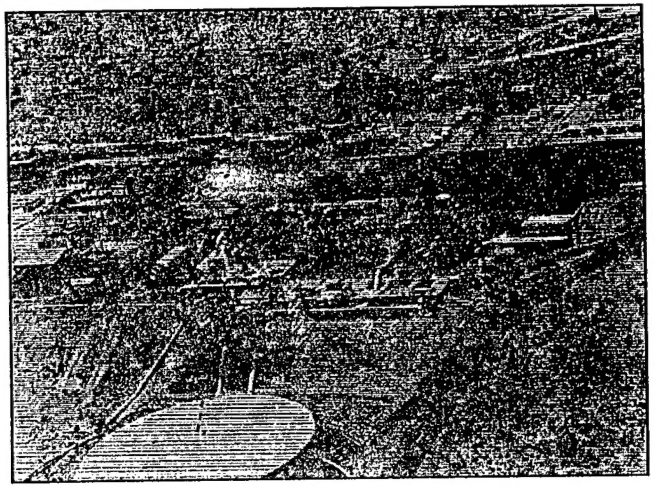


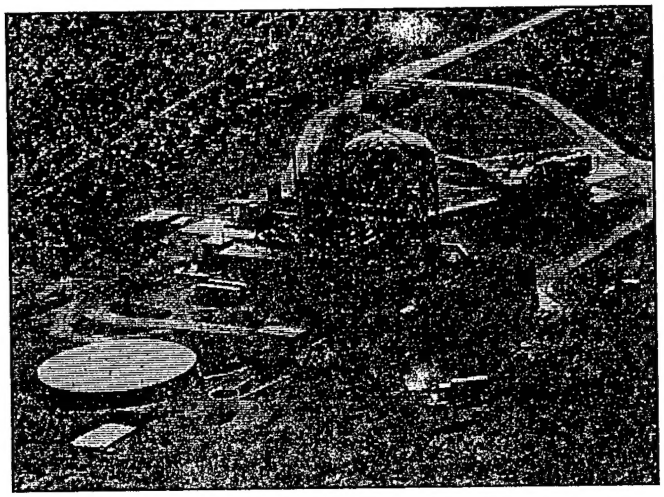


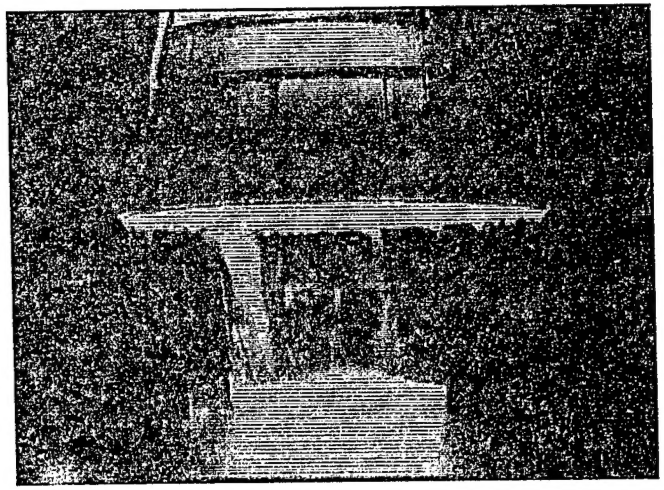
THIRTEEN SOLID ROCKET MOTOR
PADS TO 10,000,000 LBS THRUST

# Altitude Facilities

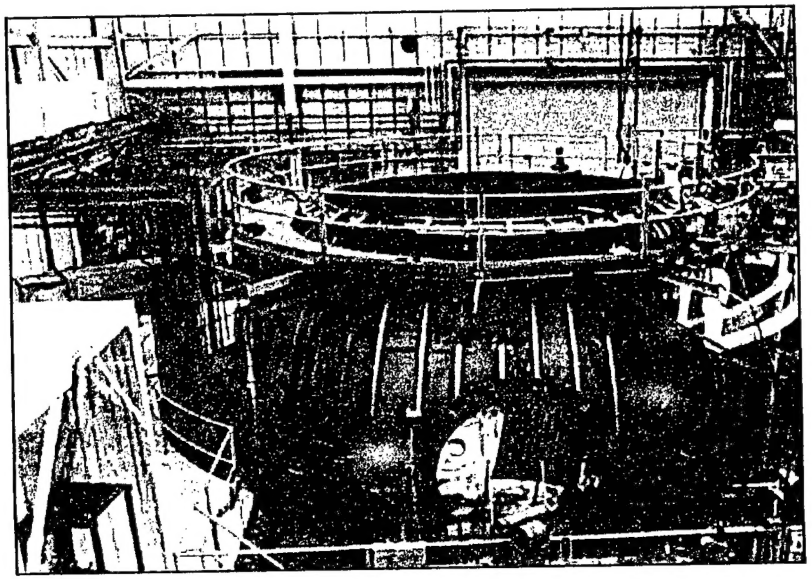
## FROM MILLIPOUNDS TO 60,000 LBS THRUST





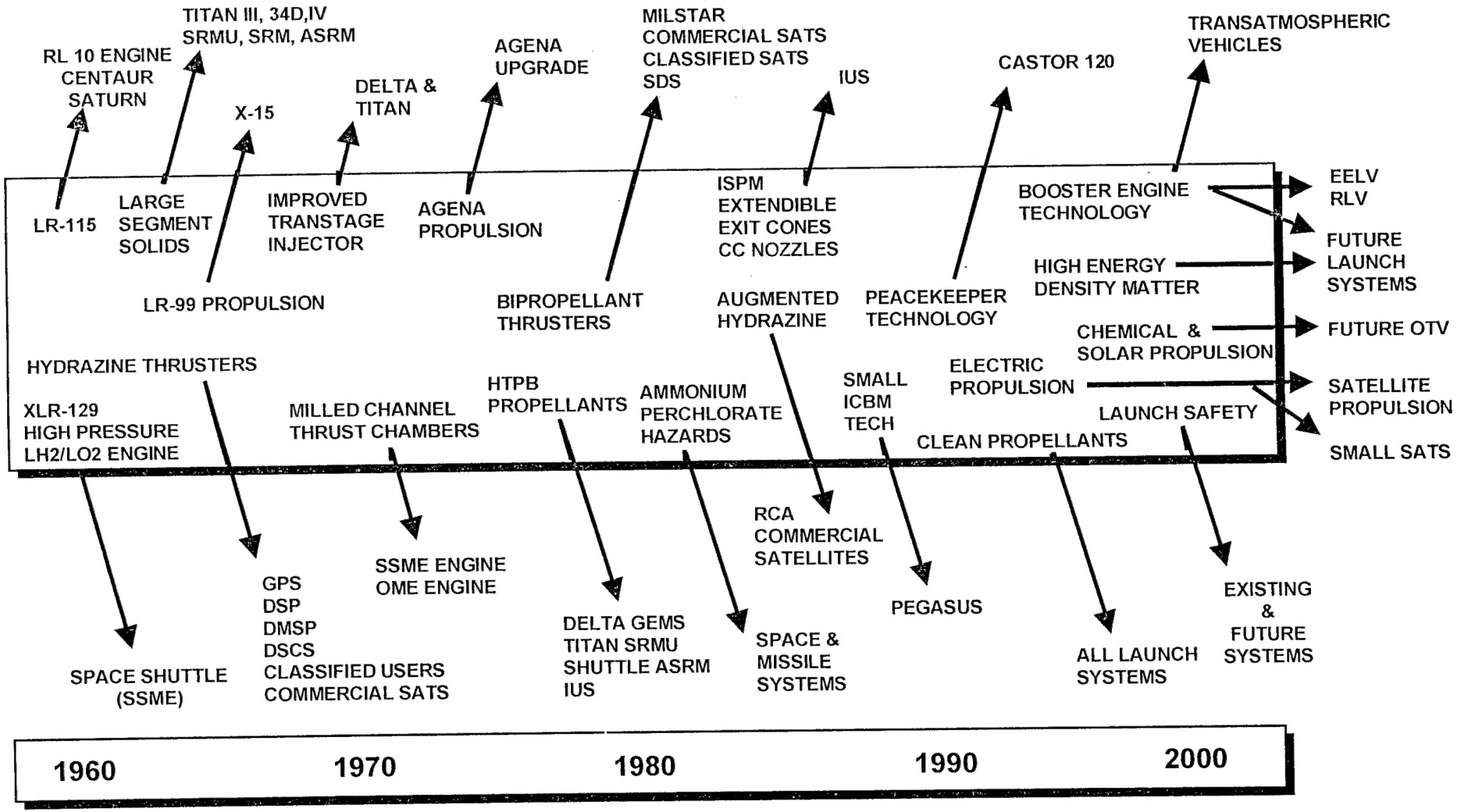


# Combined Space Environment Simulation



**30 FT DIAMETER LIQUID NITROGEN**
**COLD WALL QUARTZ LAMP SOLAR SIMULATION**

# Air Force Research Laboratory Space Propulsion Contributions



# Air Force Research Laboratory Contribution to Air Force Satellite Propulsion

SPACE MOTOR

STAR 63D

MONO-PROPELLANT

HYDRAZINE MATERIAL COMPATIBILITY

HYDRAZINE THRUSTERS & FEED SYSTEMS

BI-PROPELLANT

BI-PROPELLANT THRUSTERS & FEED SYSTEMS

DUAL SEAT VALVES

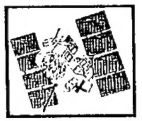
ELECTRIC PROPULSION

PULSED PLASMA THRUSTERS

RESISTO JETS*

ARCJETS

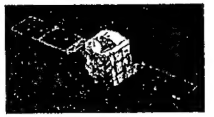
GPS



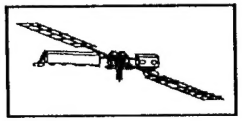
DSP

DMSP

DSCS



MILSTAR



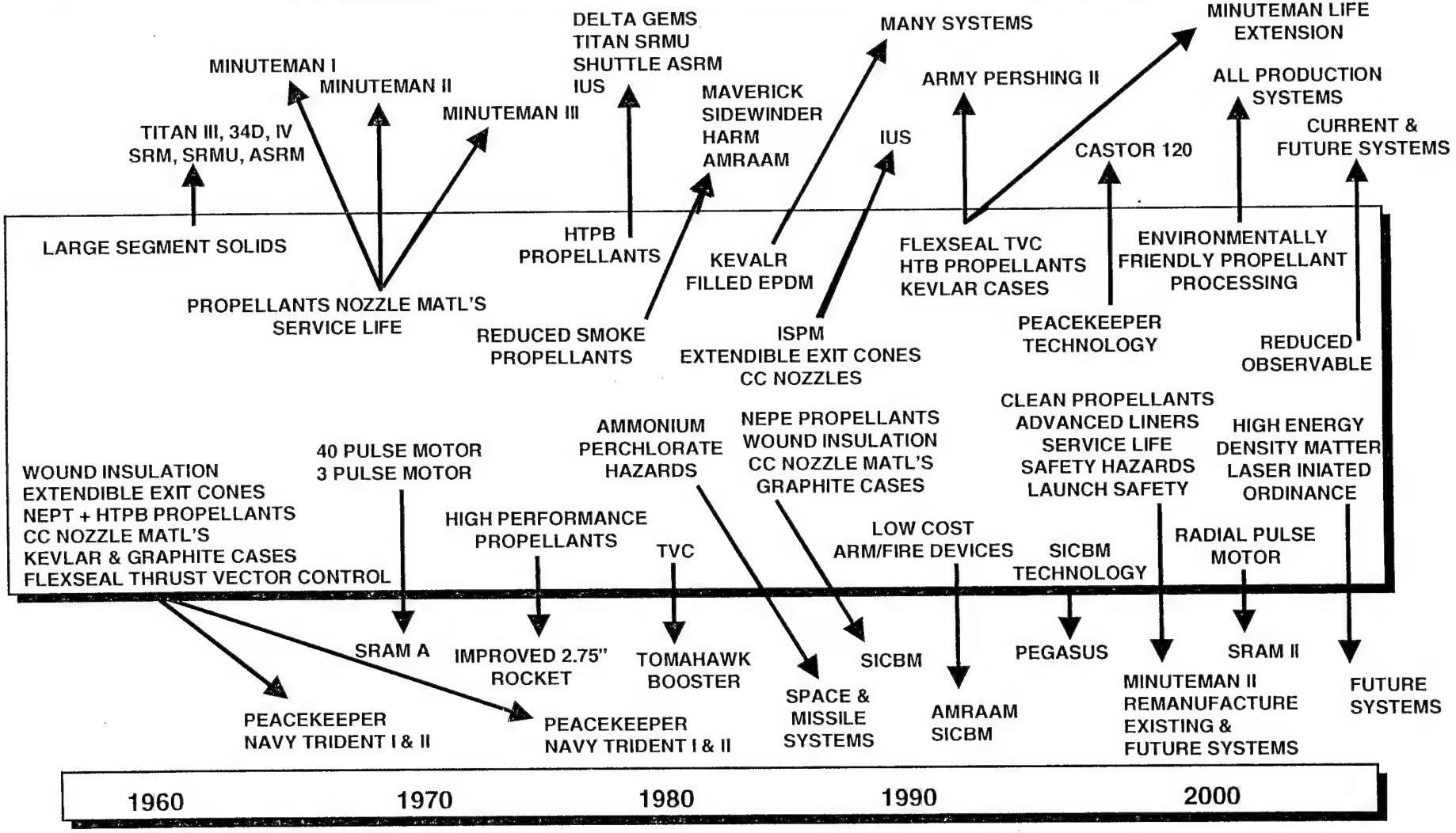
FUTURE AF SATELLITES

1960 1970 1980 1990 2000 2005

* $1M AFRL Investment Extended On-Orbit Life and Generated Over $1B Additional Income on Lockheed-Martin Commercial Satellites.

A0168..

# Air Force Research Laboratory
# Solid Propulsion Motor Technology Contributions



# Air Force Research Laboratory Contribution to Peacekeeper ICBM

## PROPELLANT

* + HTPB(HYDROXY TERMINATED POLYBUTADIENE) — STAGE 1,2
NEPE(NITRATE ESTER POLYETHER) — STAGE 3

## NOZZLE

\+ CARBON-CARBON INTEGRAL THROAT INSERT — STAGE 1,2, 3
*‡ FLEXSEAL TVC — STAGE 1,2, 3
\+ EXPANDABLE EXIT CONES — STAGE 3

## MOTOR CASE

LOW LENGTH-TO-DIAMETER KEVLAR WOUND ELASTOMERIC INSULATION — STAGE 3, STAGE 3

## PBPS

INJECTED MOLDED ATTITUDE CONTROL ENGINE THRUST CHAMBER — STAGE 4

## OTHER

NUCLEAR EFFECTS STUDIES — ALL STAGES
ORDINANCE TEST SUPPORT — ALL STAGES

**Other Applications**

* Pershing II
\+ Inertial Upper Stage
‡ Trident I (C-4)
Titan IV SRMU

**IOC DEC 86**

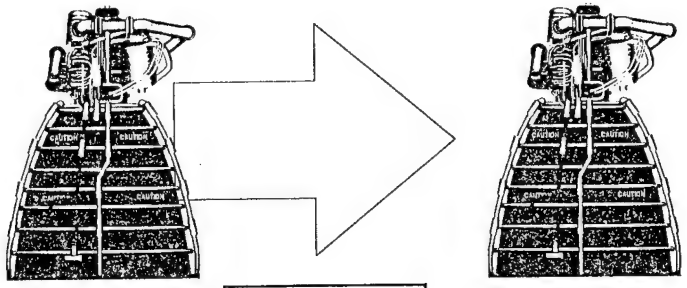
**This technology increased the payload capability by 82% over MM III technology**

1960 1970 1980

# Propulsion Related AFSPC Deficiencies

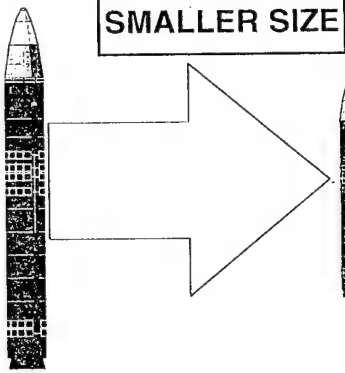
- Costly Spacelift
- Unresponsive Spacelift
- Satellite Repositioning
- Satellite Recovery & On-Orbit Service
- Global Mobility Via Space
- Lack of DoD Space System Protection Capability

# IHPRPT is....



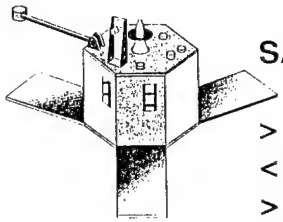
SAME SIZE

> Range / Payload
> Thrust
> Isp
< $

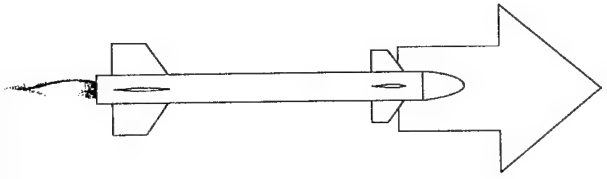


SMALLER SIZE

= Payload
= Thrust
> Isp
> $M_f$
< $



SATELLITE PERFORMANCE
SAME THRUST
> Isp or Thruster Efficiency
< $
> Life
> Repositioning Capability



THRUST CONTROL
> Range
> Warhead Delivery
> $M_f$

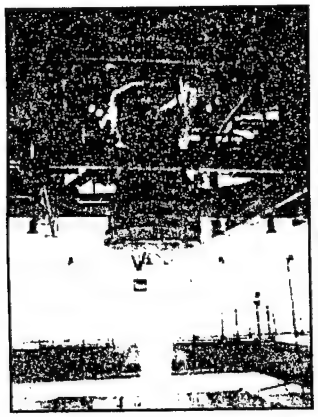
**Double Rocket Propulsion Capability By 2010**

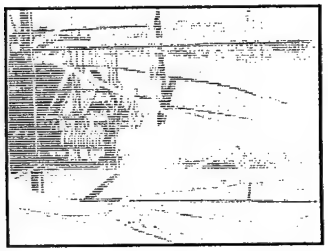
PROCESS FOR:
- Works First Time, Every Time
- High Performance Long Life
- Dual Use, Cost Effective
- Environmentally Compliant
- Insensitive, Safe
- Highly Efficient Operation

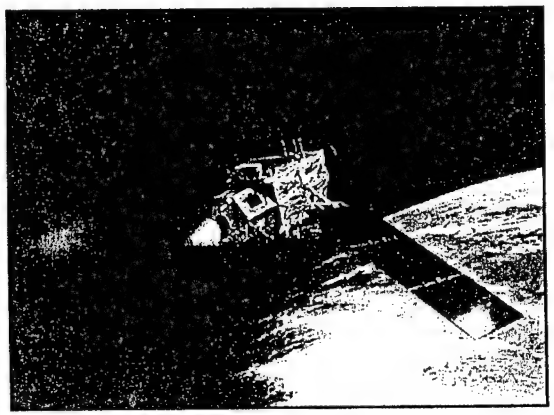
# IHPRPT Investment Impacts

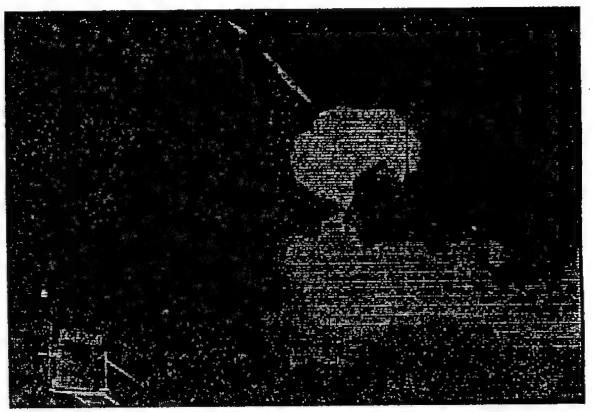
## Propulsion Performance has Major Impacts on Vehicle Size/Weight

## Propulsion Represents the Limiting Factor in Future Military and Commercial Capabilities









**PROPULSION IS...**

### Boost

70-90% Takeoff System Weight

40-60% System Cost

### Spacecraft

Life Limiting Factor

25-40% System Cost

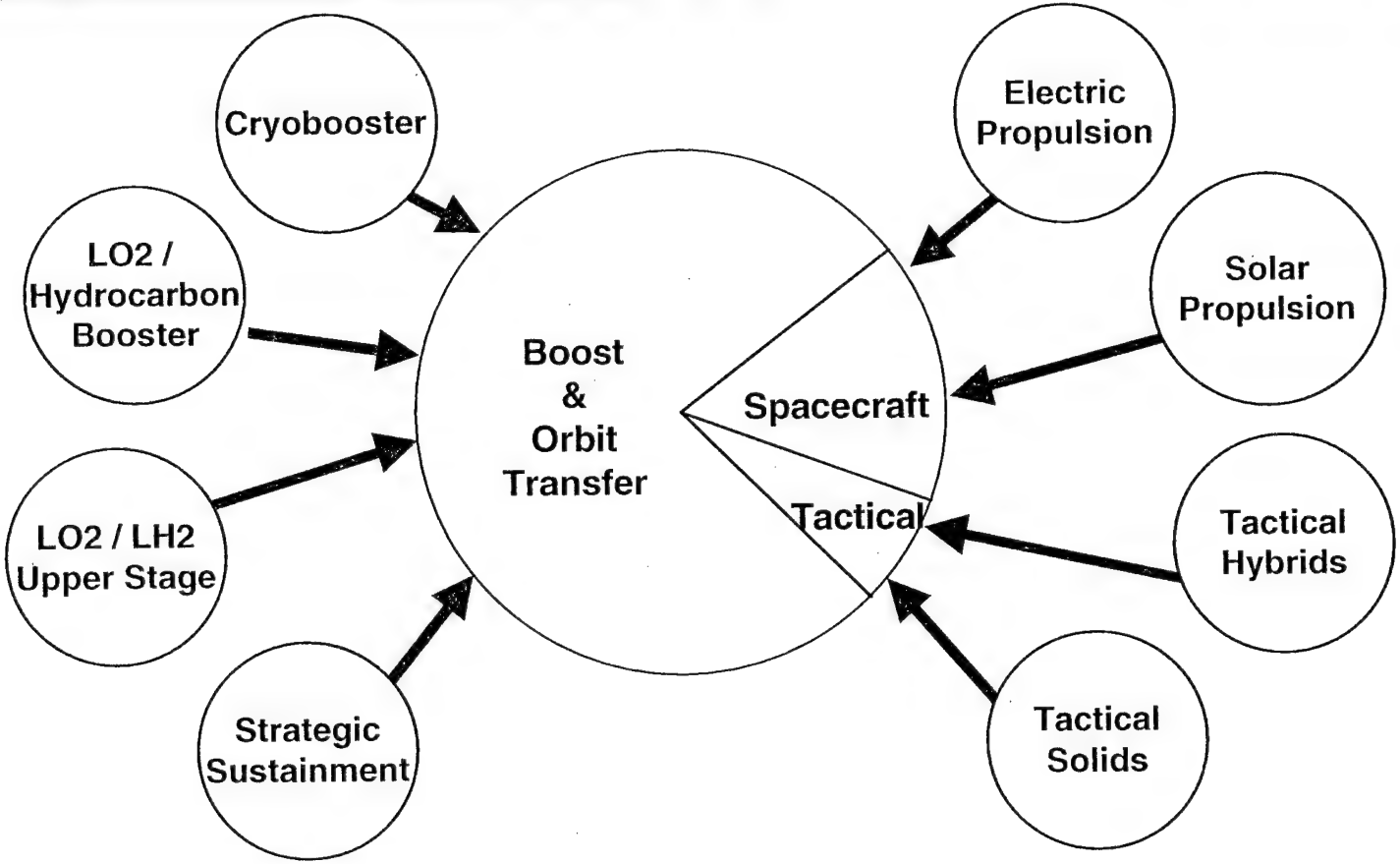
50-70% Satellite Weight

### Tactical

60-80% Missile Weight

Critical Factor in Decreasing Time-to-Target

# Propulsion Directorate Primary IHPRPT Focus Areas

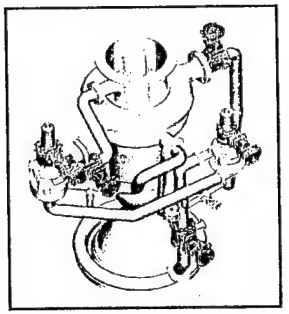



| Advanced Concepts | Advanced Propellants | Materials Applications | Aerophysics |
|---|---|---|---|

# Rocket Propulsion Division Key Programs

## Integrated Powerhead Demo

- Develop Enabling Technologies for Advanced Cryogenic Engines
- Enables Reusable Space Launch Vehicles

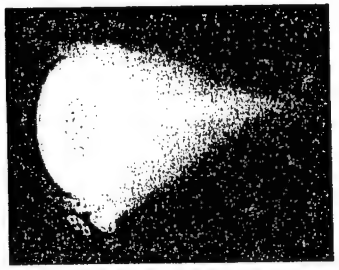


## Advanced Expander Cycle Upper Stage Engine

- Develop Technologies for the Next Generation Upper Stage Engines
- Increased Reliability, Increased Payload, Decreased Cost

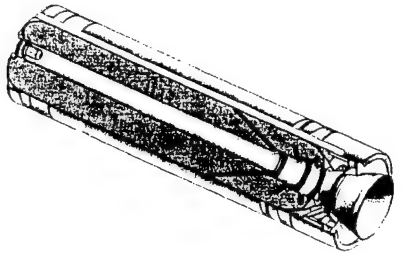
## Hybrid Propulsion

- Develop Hybrid Propulsion for Tactical, Upper Stages and Boost Systems
- Increased Operational Effectiveness, Inherent Safety and Increased Performance



## Electric Propulsion

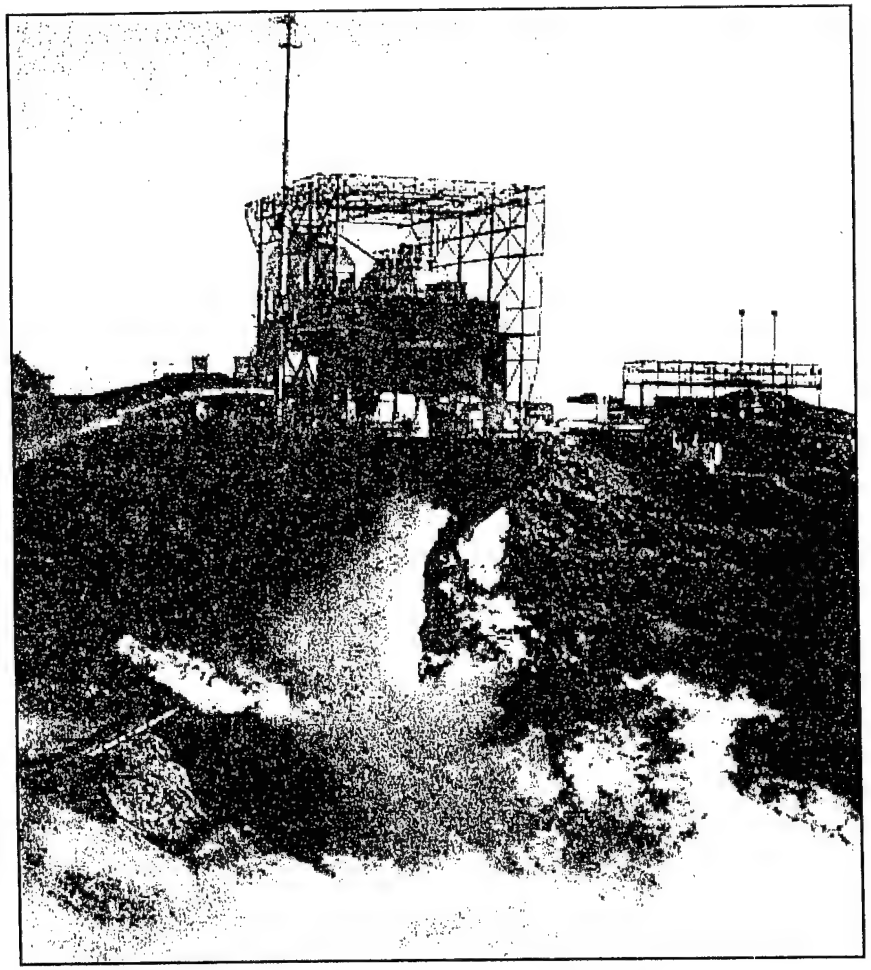
- Develop Advanced Spacecraft Propulsion
- Improved Orbit Transfer, Stationkeeping and Repositioning of Satellites



## Strategic Sustainment

- Technology Efforts for Sustainment of Strategic Systems
- Sustainment of Existing Systems and Industrial Capacity

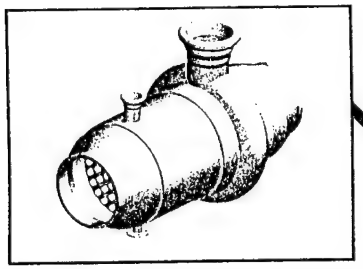
# EELV Support



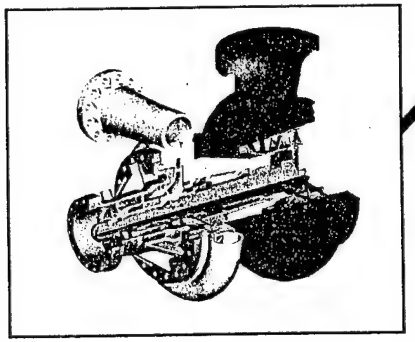
Facility System Test
9 Sep 97

- Activation of Large Engine Test Facility at Edwards AFB
- Provides EELV With Assured Engine Test Capability
- Modern World Class Rocket Engine Test Facility
- On Track to Test Rocketdyne RS-68 for Boeing EELV

# Integrated Powerhead Demonstration

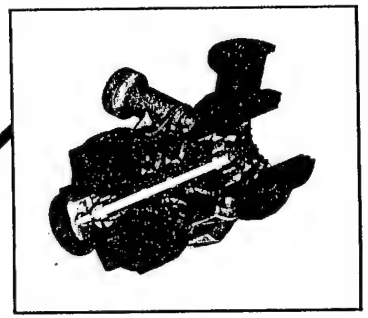


Oxygen Preburner

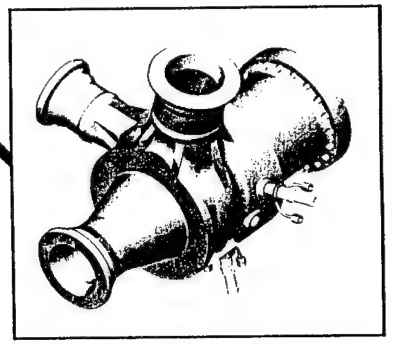


Oxygen Turbopump

**DESIGNED FOR LOWEST LIFE CYCLE COST**



Hydrogen Turbopump

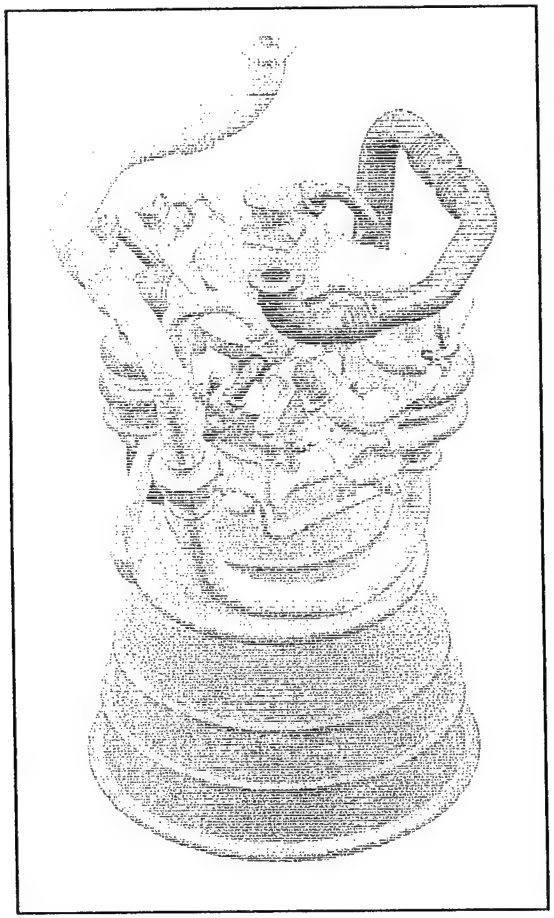


Hydrogen Preburner

**10X Increase in Engine Life**
**10X Reduction in Maintenance Cost**
**60% Reduction in Vehicle Size**
**Meets Military Spaceplane Requirements**

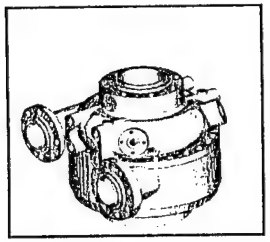
# Integrated Powerhead Demonstration

- Reusable Space Engine Technology Program
- Baseline Approach for Military Spaceplane
- Unique Design Enables 100 Missions w/o Overhaul
- Low Cost, Low Part Count, High Reliability
- Component Fabrication Underway



250K $LO_2/LH_2$ BOOSTER ENGINE

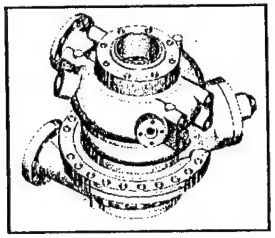
# Advanced Expander Cycle Engine Demo



LH2
Turbopump

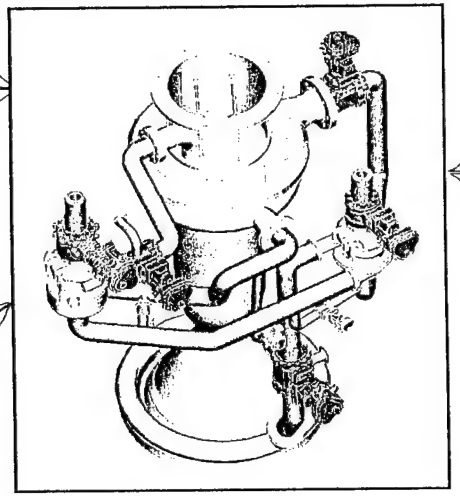
AFRL

AFRL & P&W
Upper Stage Demo



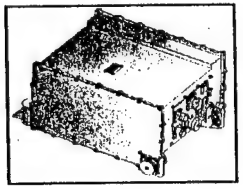
LO2
Pump

P&W



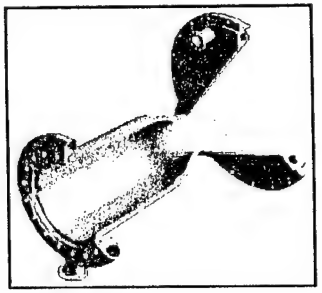
DEREC
EMA's

AFRL



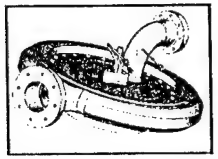
AFRL

Combustor



Injector

P&W



# Advanced Expander Cycle Engine IHPRPT Phase I Payoffs

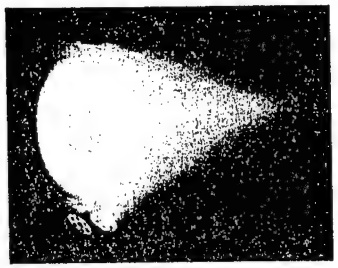
- Upper Stage
  - –Increase Payload 11%-16%
  - –Decrease Cost 5.6%
- Other Applications
  - –Booster
  - –Sustainer
  - –Military Space Plane

# Future DoD/Commercial Satellite Trends

- Greater Repositioning Requirements
- Higher Specific Power
- Greater Resolution
  - Distributed Apertures
  - Large Deployables
- Orbit Insertion
- Electric Propulsion Approaches

## Larger GEO Satellites

High Power Available
High Thrust Desired

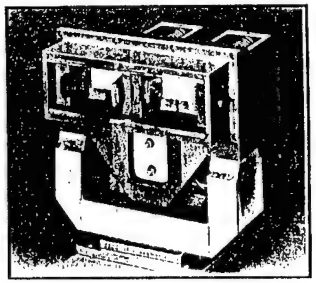


Hall
Thruster

## Small Sats

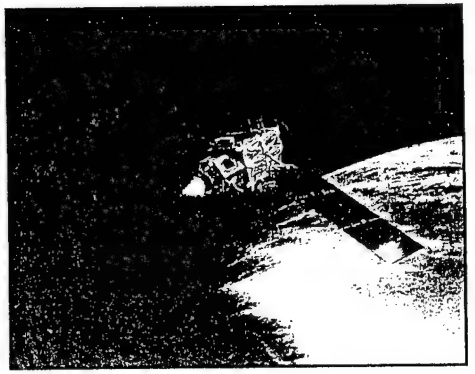
Low Power (<200W)
Small Impulse Bit

Pulsed
Plasma
Thruster

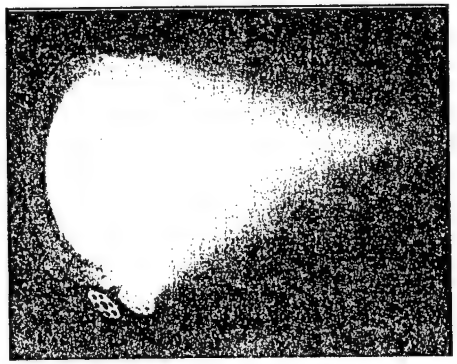


# Electric Propulsion

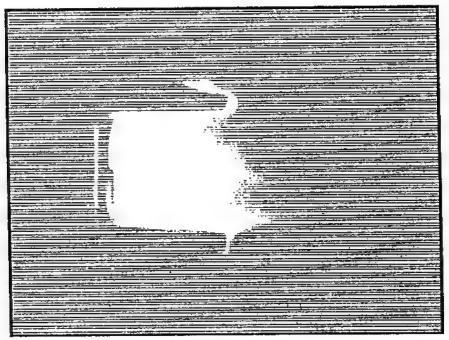
**SPACECAST 2020 - Critical Technology for Future of the Air Force**



**New World Vistas - Enabling technology, recommends aggressive R&D effort**



- Propulsion Directorate demonstrating Hall & Pulsed Plasma Thrusters
- Leading agency conducting fundamental research on Electric Propulsion



- Enables dramatic increases in GEO payloads
  50 % near term and 300% far term increase
- Enables New Missions, Special Orbits
  500% increase in Maneuvering

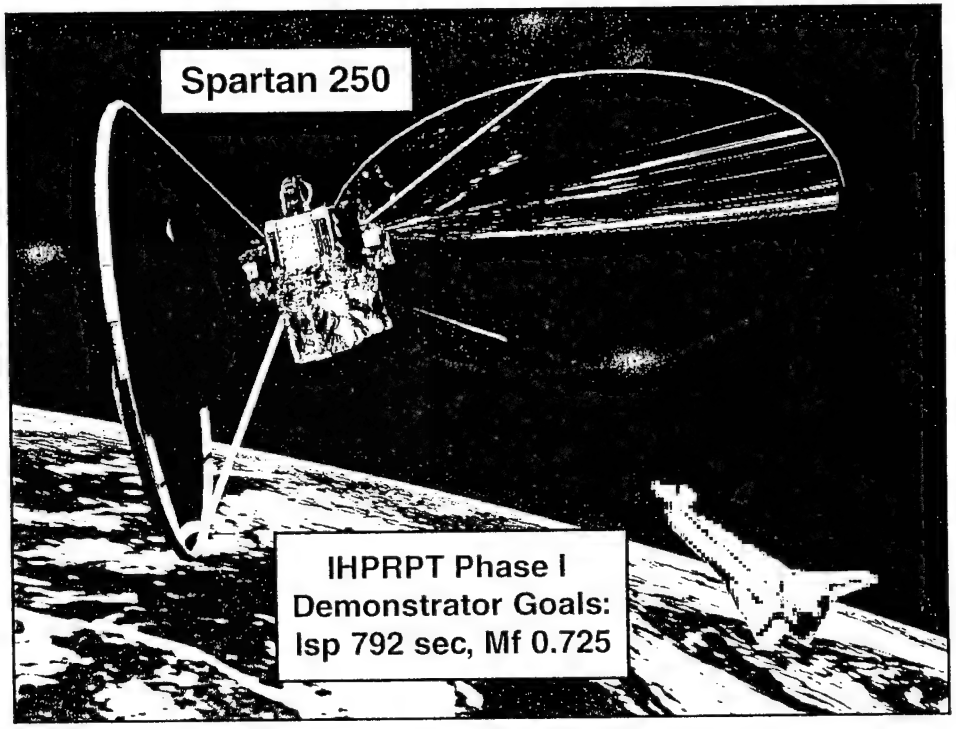
# Solar Thermal Propulsion Critical Flight Experiment

## CFE Objective

- Validate inflatable concentrators
  - Deployment and pressurization
  - Optical performance 2mrad
  - Space debris, AO, UV radiation
- Demonstrate Solar Thermal Propulsion System
  - Pointing and control .1 deg
  - Integrated engine and collector
  - Plume/mirror interactions
- Meet IHPRPT Performance Goals

## Secondary Inflatable Experiments

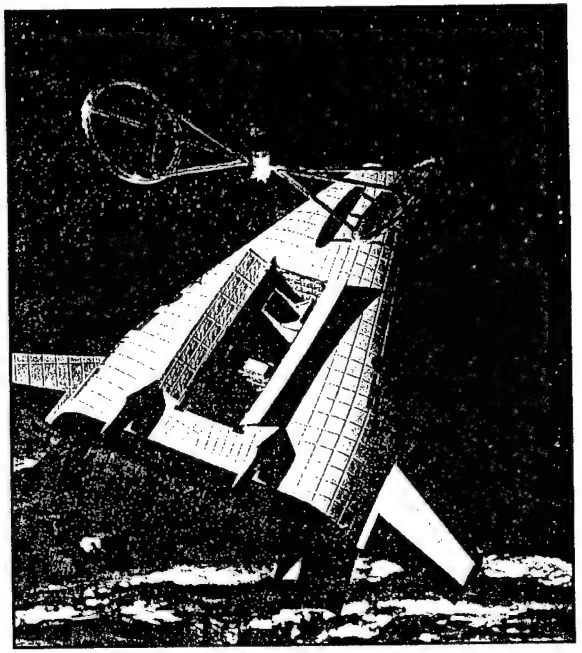
- Microwave Antenna Characterization
- PV array deployment




## Flight Experiment

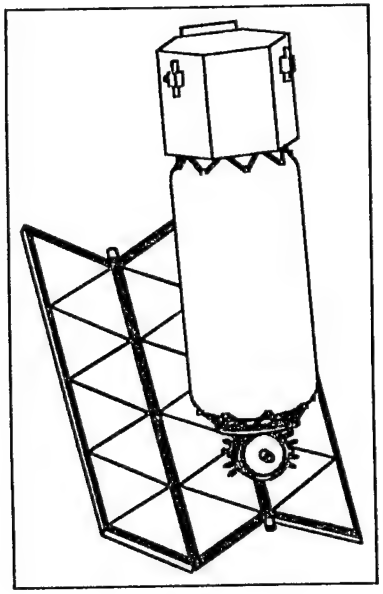
- Cooperative program with NASA
- Spartan/Shuttle launch
- Inflatable characterization
- Multiple GN2 burns
- Experiment recovered by shuttle

# Solar Thermal Propulsion Critical Flight Experiment

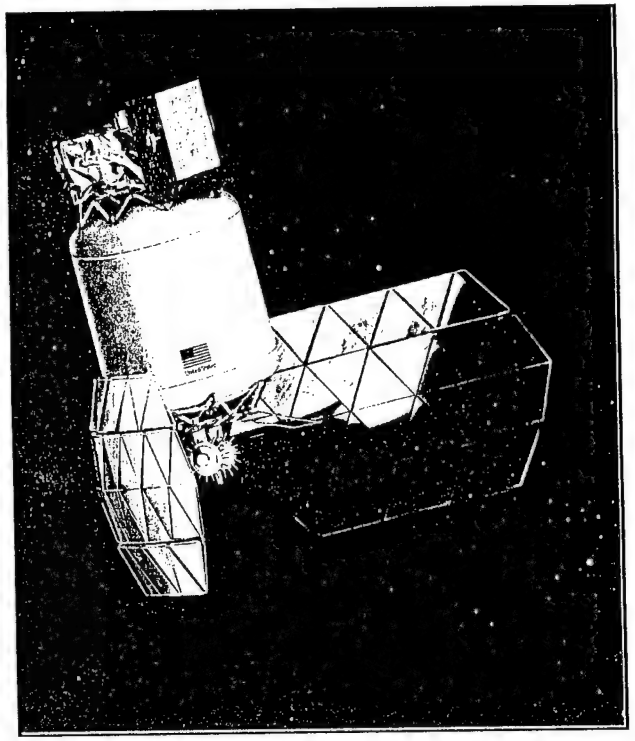


- Provides AFSPC with
  - Affordable Spacelift (2X payload to GEO)
  - Responsive Spacelift (Step down, <30 days)
  - Space Control (tug for repair,retrieval, denial)
  - Step toward high Isp Reusable OTV
  - Large aperture space antennas
- Alternatives
  - EP & chemical
  - Nuclear & Laser Thermal
  - AFRL SOTV/ISUS
  - NASA Shooting Star
- Need for Space Flight
  - Test 0g inflatable deployment dynamics and accuracy
  - Test 0g, free flight tracking and control for large inflatable structures
  - Quantify effects of LEO environment (Solar Flux, UV, AO, Debris)
  - Demonstrate solar thermal propulsion in operational space environment

# AFRL SOTV



- Power and Propulsion
- Thermal storage cavity
- Single smaller rigid segmented concentrator
- Cryo H2 storage and delivery
- Tankage interaction
- Thermionic operation
- EELV 2002 launch



# Strategic Sustainment

- **USSTRATCOM Initiated Program**
  - Meets the USSTRACOM Requirement for Sustainment of Strategic Technology
  - Funding Directed by Dr. Kaminski
  - $67M Fenced Funding from FY98 Through FY03
- **Coordinated with the MM SPO**
  - OO-ALC/M
  - SAF/AQS
  - SMC/XRT
  - USSTRATCOM/J541
  - HQ AFSPC/DRM, DOM
- **SPO PRP Deals with Existing System**
- **Strategic Sustainment Deals with**
  - Future Technology
  - Sustainment of Propulsion Development Capability

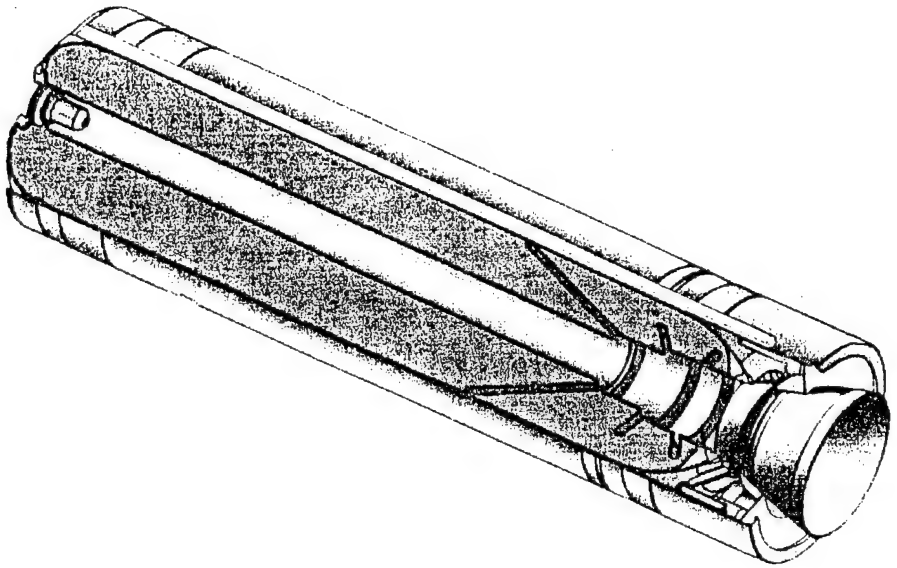
# Strategic Sustainment and PRP

- **Two Different Programs with Two Different Objectives**

| SS | PRP |
|---|---|
| Lab Program | SBICBM SPO Program |
| Technology Development | System Maintenance (Propellant Repour) |
| Sustains Motor Development Capability | Sustains Existing System |
| Component Design | Manufacturing |

- **PRP Only Does that Technology Needed to Keep Minuteman Operating**

# Strategic Sustainment Missile Propulsion

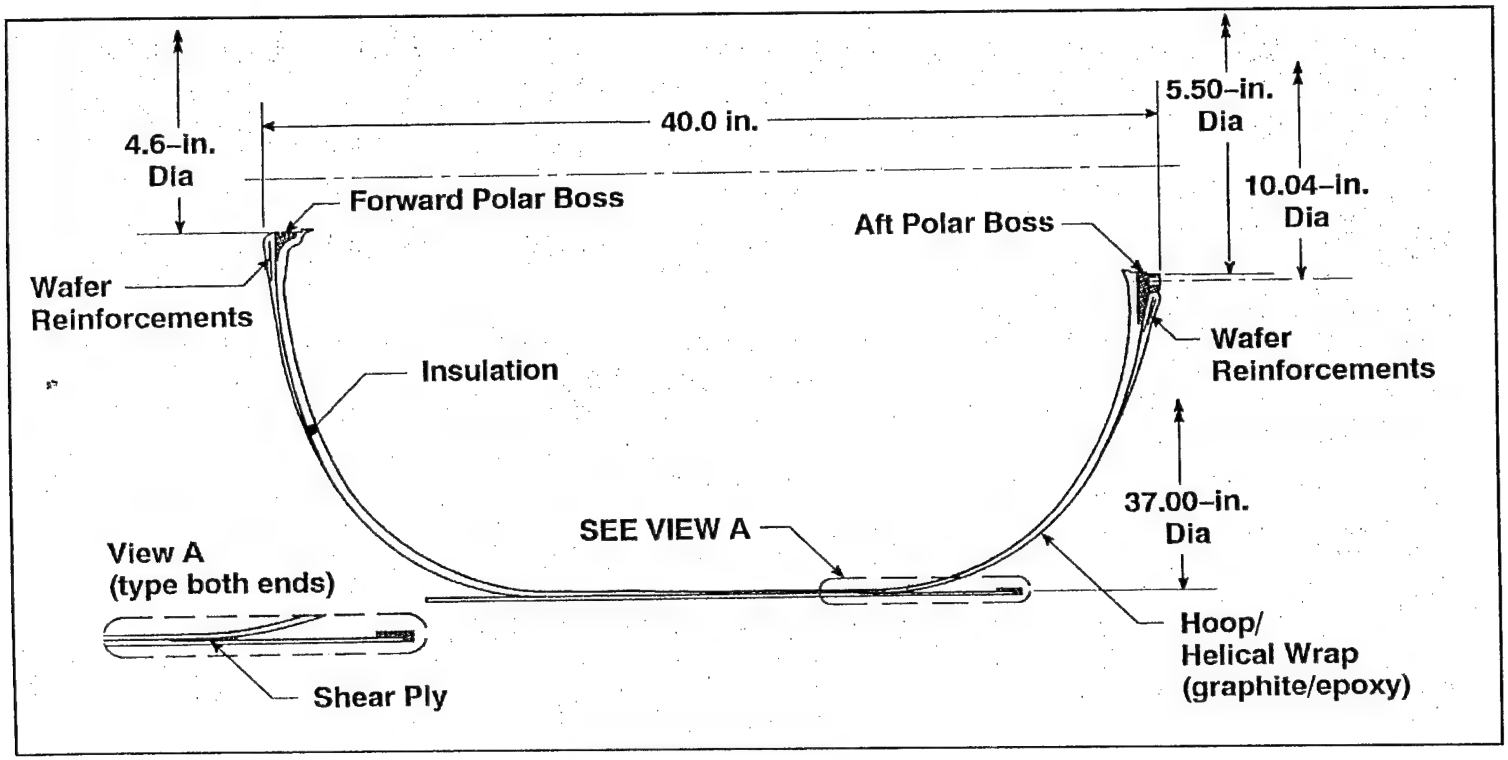


SUSTAINMENT MOTOR

- Propellant
  - Sustainable Ingredients
  - Reduced Hazards Class 1.3
- Nozzle
  - In-Situ Densification
  - Low Cost Ingredients
- Stronger, Lower Cost Case
- Electromechanical Actuators
- Support & Hardware Cost Reduction - 25%
- Inert Weight Decrease - 15%
- Isp Increase - 4% (10 sec)

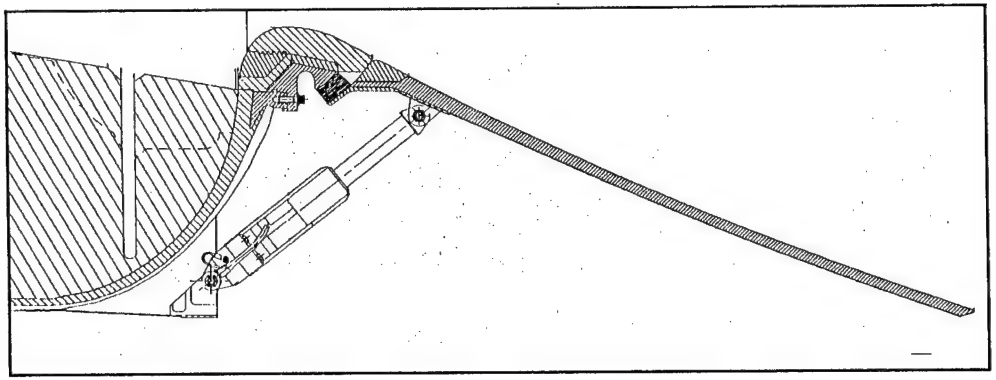
# Case (Thiokol)

- Reduce Case Weight by 13.7% (Increase Castor 120 Mass Fraction 1%)
- Reduce Case Cost by 23% (Decrease Castor 120 Cost 6%)



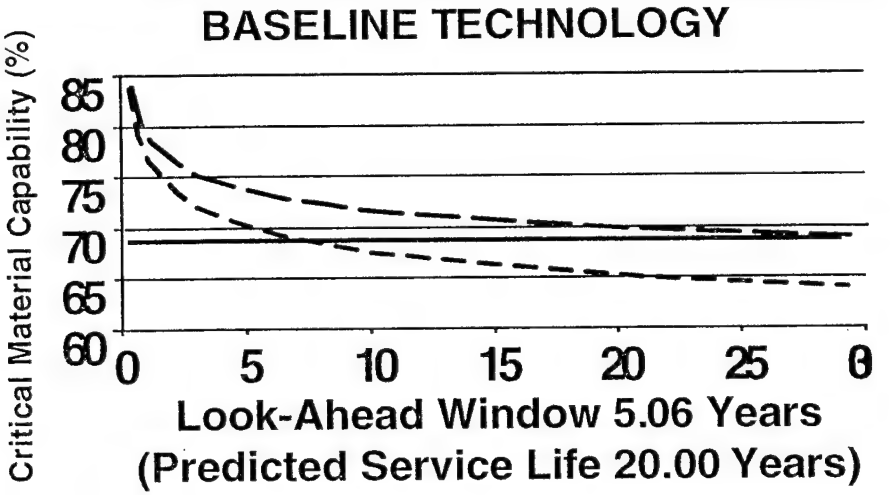
# Supersonic Splitline Flexseal Nozzle

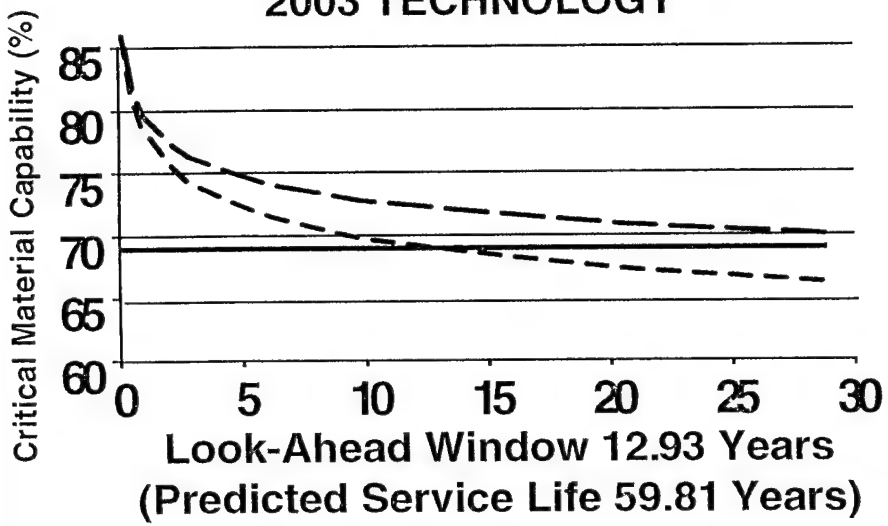
- Method to Build a Lighter and Less Complicated Nozzle
- Improves the Payload of an NMD Missiles' Second and Third Stage by 9% (even when the Length of the Missile was Constrained)
- Applied to the Orbus 1® Motor Which was used to Demonstrate the concept
  - Nozzle Weight can be Reduced by 43%
  - Nozzle Cost Can Be Reduced by 20%
  - Propellant Weight can be Increased by 1%



SUPERSONIC SPLITLINE FLEXSEAL APPLIED TO ORBUS-4 MOTOR

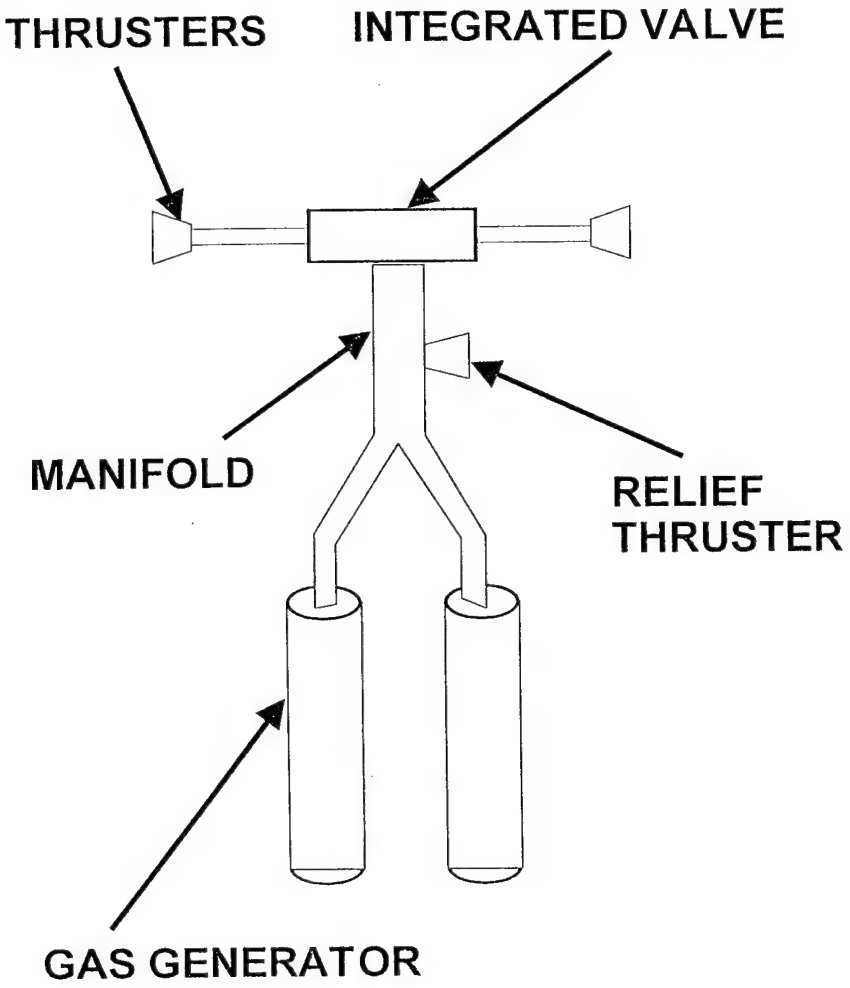
# Strategic Sustainment Aging and Surveillance




- Address Both Analytical and Surveillance Technology
- Decrease Analysis Procedure, Aging Model & Material Characterization Uncertainties
- Extend "Look-Ahead" Window to 10 Years With 90% Confidence Level
- Develop Techniques That Permit Individual Motor Predictions
- Reduce Time and Cost for Non-Destructive Evaluation Data Processing by 50%

# Strategic Sustainment
# Post Boost MIRV Propulsion



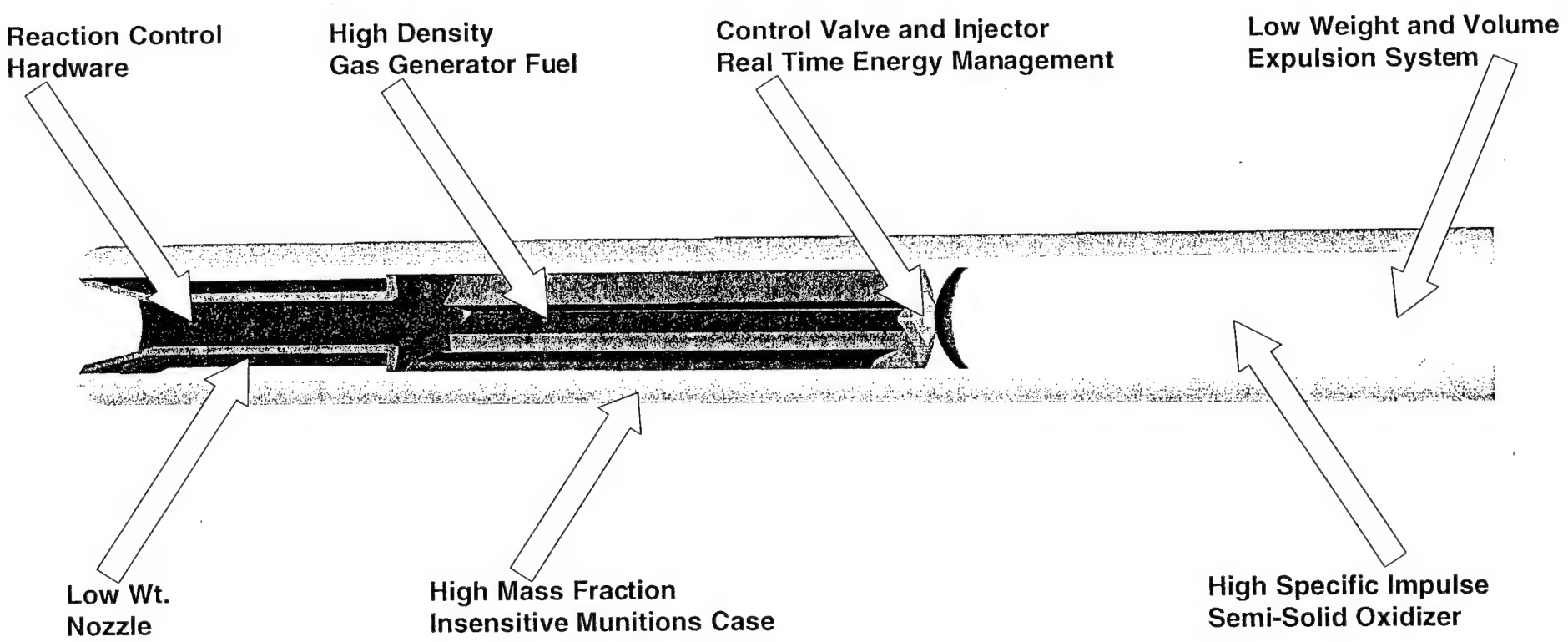

## Solid System

- Uses Composite Materials
  - Eliminates Unique Materials
- Uses 1.3 Propellant
  - Reduces Hazards
- Reduces Cost by 25% While Maintaining Performance

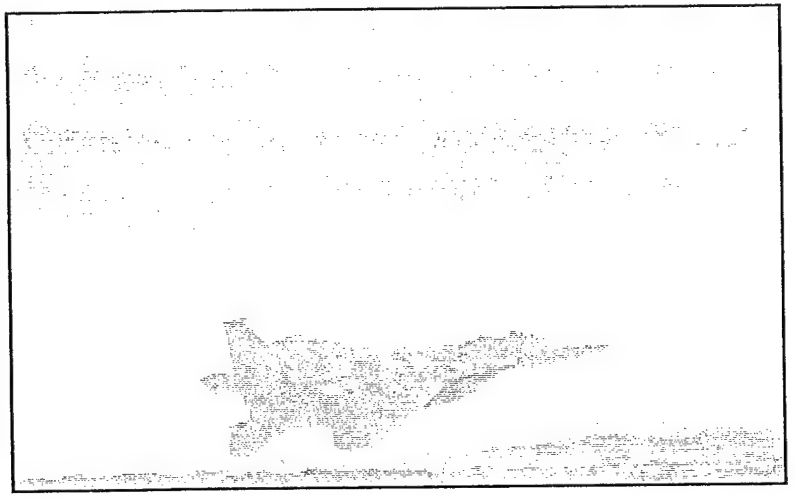
## Liquid System

- Uses Non-Toxic Propellants
- Reduces Cost 35%
- Reduces Weight 50%

# Phase II
# Tactical Hybrid Demonstrator Configuration



# The Pay Off

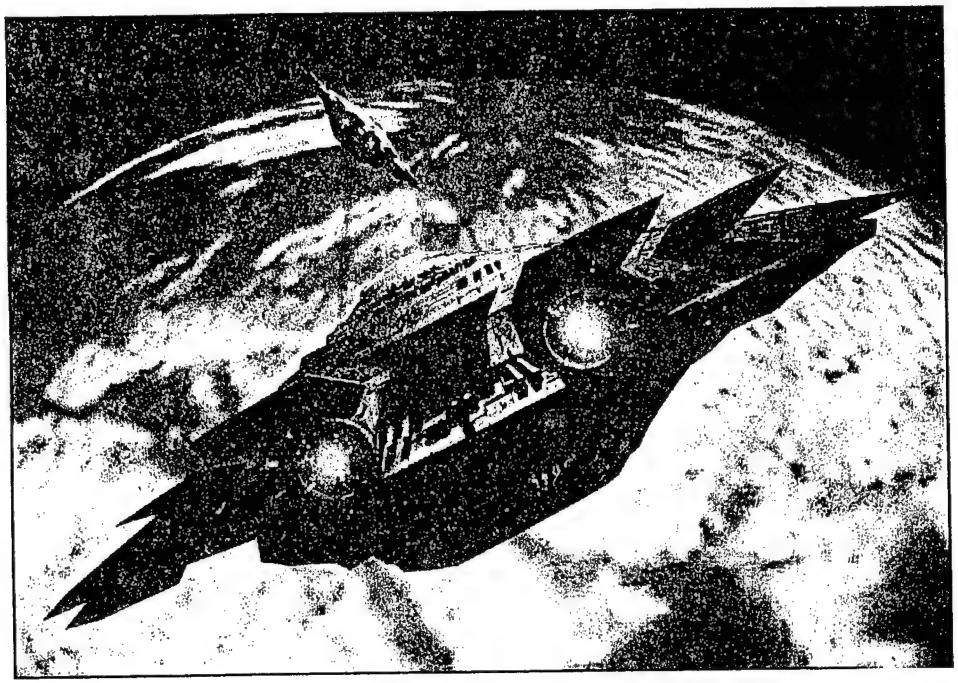


- 16% Increase in Average Velocity
- 13% Increase in F-Pole
- 8% Increase in A-Pole

# AFRL / PRR
# 6.2 & 6.3 New Project Starts

- **FY99**
  - Light Weight Engine Nozzle
  - Phase I Solid Boost Demonstrator (6.3)
  - Critical Defect Assessment Program
- **FY00**
  - High Temperature Oxygen Turbine Development
  - Single Stage High Discharge Pressure LH2 Turbopump
  - Electric Propulsion System for Orbit Transfer (6.3)
  - Strategic Sustainment Demonstration (6.3)

# Propulsion Technology Enabling Future Space & Air Force Systems



- Low Cost Access to Space
- Airplane Like Operations
- Routine Space Transition Operations
- Satellite Maneuvering and Repositioning
- Missile Defense and Space Control
- New Space Based Systems
  - Space Based Radar

# Conclusion

## ROCKET PROPULSION DIVISION

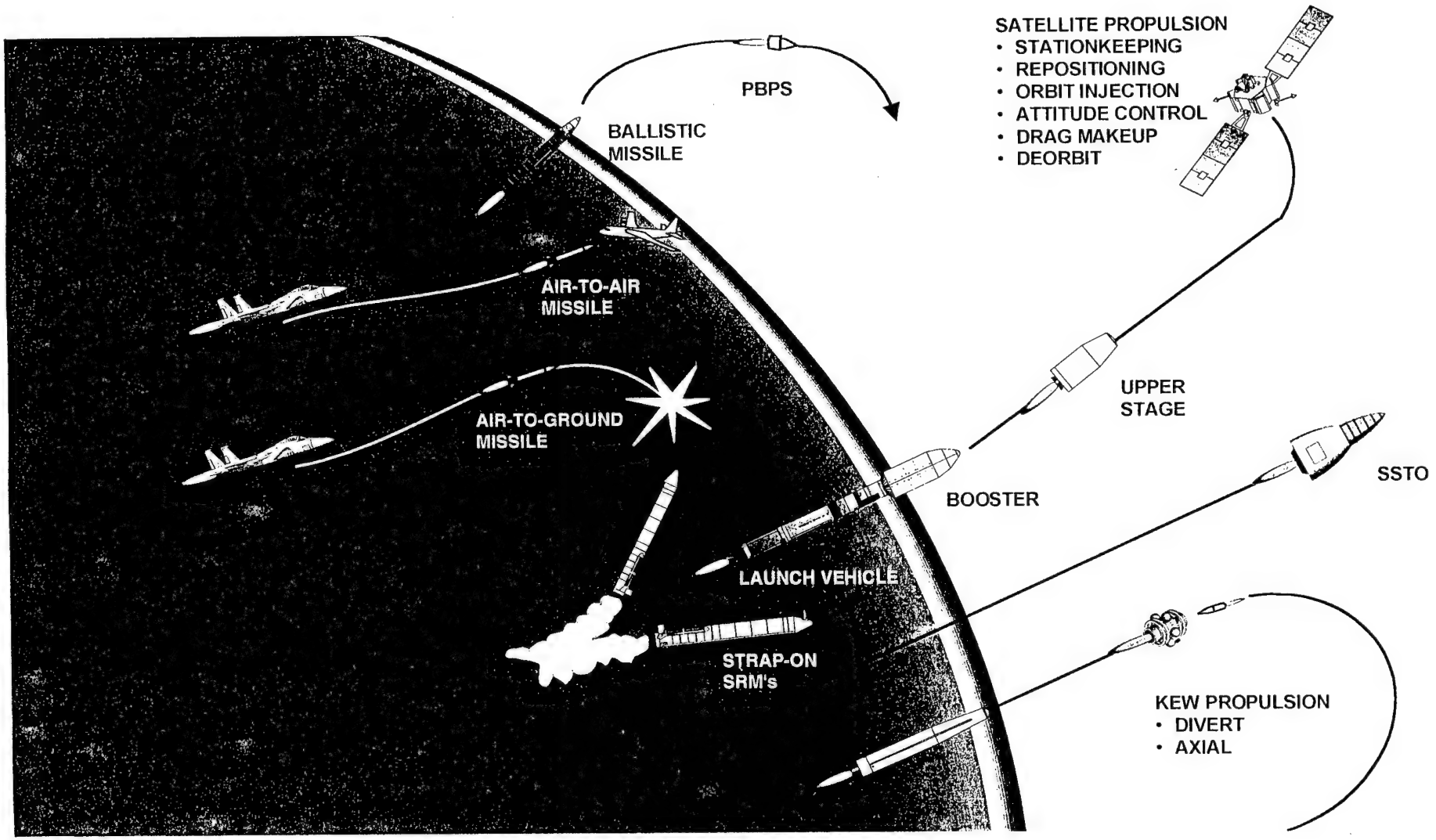
- GUARANTEED to support the warfighter
  - Close bond between PL and AFSPC
- Honest Broker / Expert Consultant
- One Place gives Full Spectrum Capability (Unique Facilities)
- A Center of Excellence for Propulsion
- Innovative Research
- Corporate Responsibilities

**THE MAJOR NATIONAL LOCATION**

**FOR ROCKET PROPULSION**

**TECHNOLOGY**

# Rocket Propulsion Technology
# Fundamental to all Space & Missile Systems



# Tactical Propulsion Minimum Smoke Propellant Development

## Objective

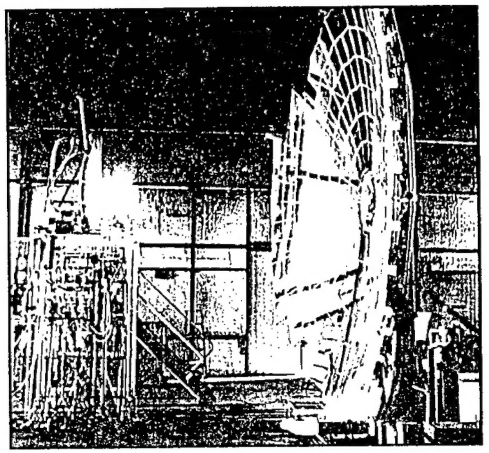
- Demonstrate Next Generation of Low Hazards, High Performance, Low Signature Propellants

## Approach

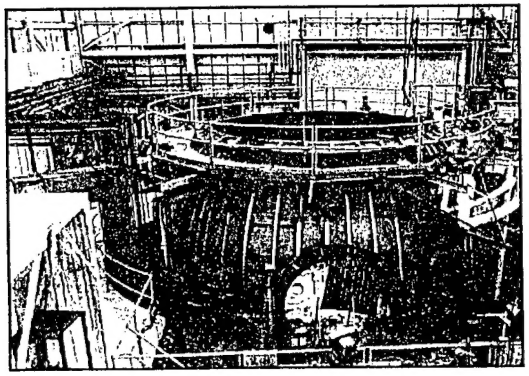
- Air Senior National Representative (ASNR) Sponsored Effort
  - France: Ballistics & Hazards
  - Germany: Formulation Characterization & Performance Calculations
  - United Kingdom: Mechanical Properties & Aging
  - U.S.: Formulation Characterization, Ingredient Analysis & Performance Calculations

# Solar Propulsion Laboratory

## World Class Facilities



- ONLY U.S. SOLAR FACILITY USING LH2
- 10000:1 CONCENTRATION RATIO
- 3400K GAS TEMPERATURE



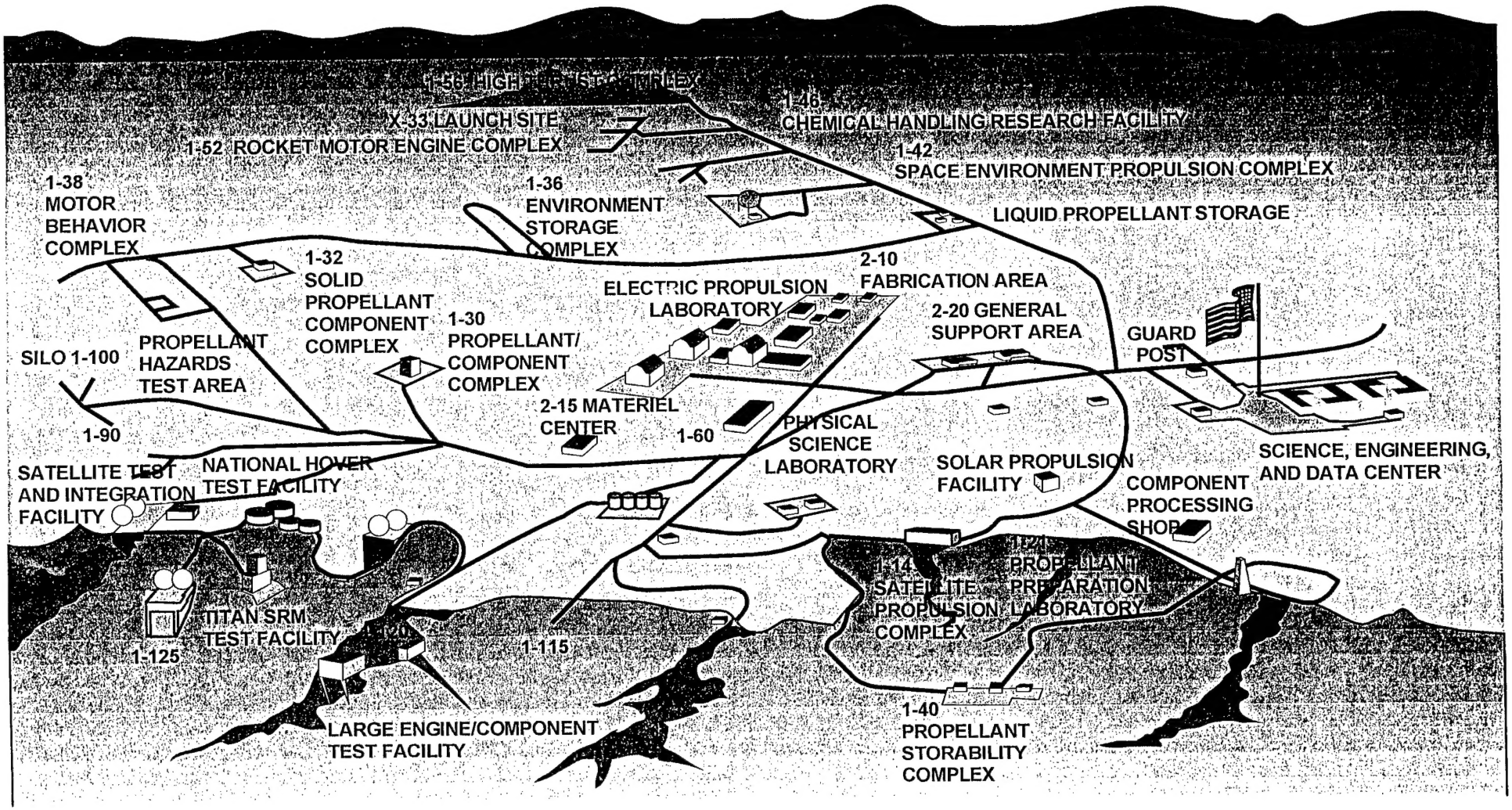
- 30 FOOT DIAMETER VACUUM SPHERE
- ONLY LARGE U.S. VACUUM FACILITY RATED FOR 100,000 LBS LH2

## Center of Excellence for U.S. Solar Efforts

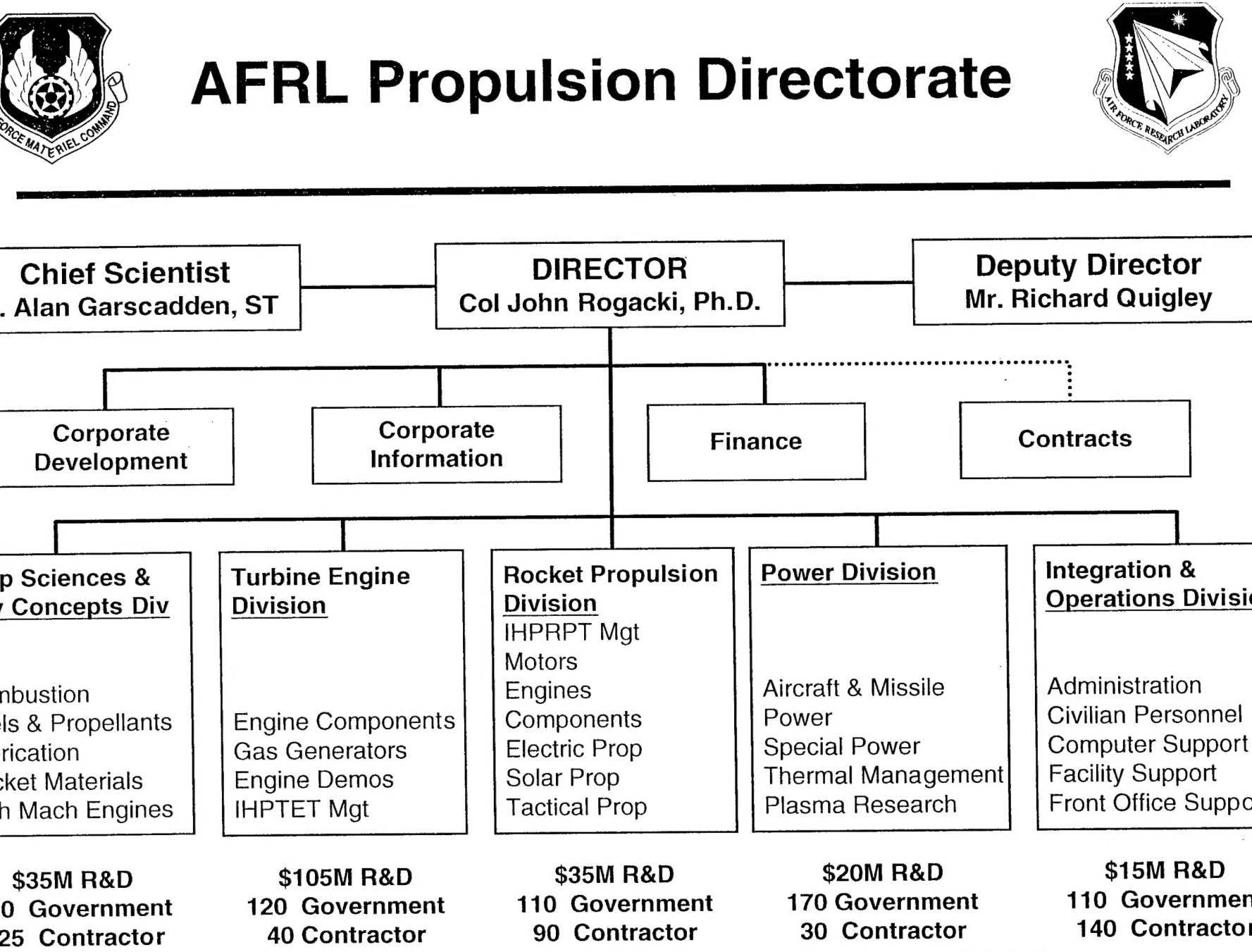
- Laser Power Beaming (PL/LI)
- Solar Bimodal Propulsion and Power (PL/VT)
- Industry / AF / NASA / University Solar Consortium CRDA
- Hercules CRDA
- Commercial Spin-Offs
  - High Temperature CC Springs
  - Holographic Embossed Thin Films for Medical CATscans
  - Compressed Natural Gas Bladders for Chrysler Corp.
  - Polyimide Concentrators for Space Based RF Antennas

# Propulsion Directorate

## Rocket Propulsion Facilities

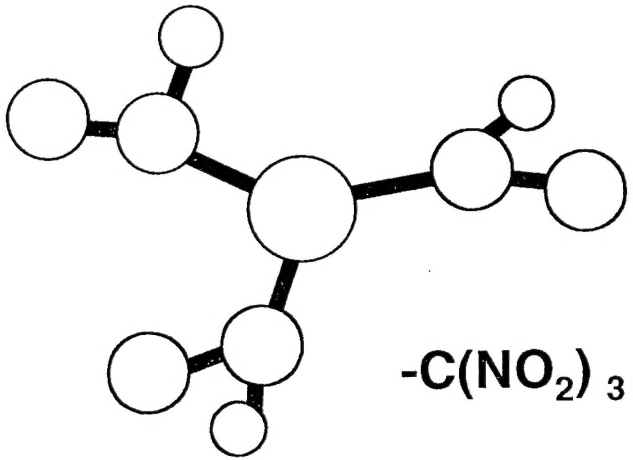


# AFRL Propulsion Directorate




FY98 Data

# New Energetic Monopropellants




## Payoff

- Double Satellite On-Orbit Lifetime
- Non-Toxic Replacement of Hydrazine
- Candidate for Military Space Plane

## Approach

- Low melting salts, dissolved in solvents
- Low volatility, low toxic

## Status

- Several candidates synthesized
- Low shock sensitivity, low cost

| Candidate Propellants | Isp (sec)* | p (g/cc) |
|---|---|---|
| • Hydrazine | 198 | 1.00 |
| • Peroxide | 164 | 1.43 |
| • XM46 (HAN/TEAN) | 244 | 1.43 |
| • RKS-M1 | 270 | 1.69 |

* Pc=1--- psi, Sea Level exhaust